Distribution of the estuary stingray (*Dasyatis fluviorum*) in Australia

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ABSTRACT

The extant distribution of *Dasyatis fluviorum* Ogilby, 1908 is confined to rivers, estuaries and near-shore marine waters along approximately 1700 km of the eastern Australian coastline from central New South Wales (34° 4´ S) northwards to central Queensland (20° 37´ S). Records of *D. fluviorum* from northern Australia, Papua New Guinea and eastern Indonesia appear to be misidentifications of *Dasyatis* sp. 1 (as described by White et al. 2006). An analysis of historical records shows no evidence of a contraction in distribution in south-eastern Australia as had previously been reported. However, the preferred habitats of *D. fluviorum* are heavily impacted by human activities throughout much of its range. ❐ *Biogeography, Chondrichthyes, Myliobatiformes, elasmobranch, distribution, conservation.*

Six of the seven freshwater and estuarine-specialist elasmobranch species in Australian waters (Last 2002) are listed as globally threatened on the 2007 IUCN Red List of Threatened Species (IUCN 2007). Little is known about the elasmobranch species inhabiting estuarine and mangrove ecosystems, though these habitats have suffered extensive modification and degradation from anthropogenic processes worldwide (Halpern et al. 2007; Lotze et al. 2006), and the sharks and rays that prefer to inhabit these environments may have suffered concomitant population declines (Compagno 2002; Last 2002). This situation is exemplified by the estuary stingray (*Dasyatis fluviorum*) Ogilby, 1908.

Dasyatis fluviorum is known from a number of rivers, estuaries and adjacent coastal waters on the highly-urbanised eastern coast of Australia (Last 2002). These areas are subject to a variety of anthropogenic pressures including urbanisation, habitat degradation, aquaculture and major fisheries, all of which are likely to impact on this species (Kyne et al. 2003; Pogonoski et al. 2002). The estuary stingray was listed as Vulnerable on the 2003 Red List of Threatened Species (Kyne et al. 2003) based on an apparent range contraction along the New South Wales (NSW) coast and anecdotal reports of population declines over the species' range (Last 2002; Last & Stevens 1994; Kyne et al. 2003; Pogonoski et al. 2002). The extant distribution of this poorly-known species has remained unclear (Last 2002; Pogonoski et al. 2002). Here we review all published literature, collate museum collection records and summarise unpublished sighting records to delineate the historical and extant distribution of the estuary stingray in Australasia.

MATERIALS AND METHODS

All available references and sighting records for *D. fluviorum* were located in the peer-

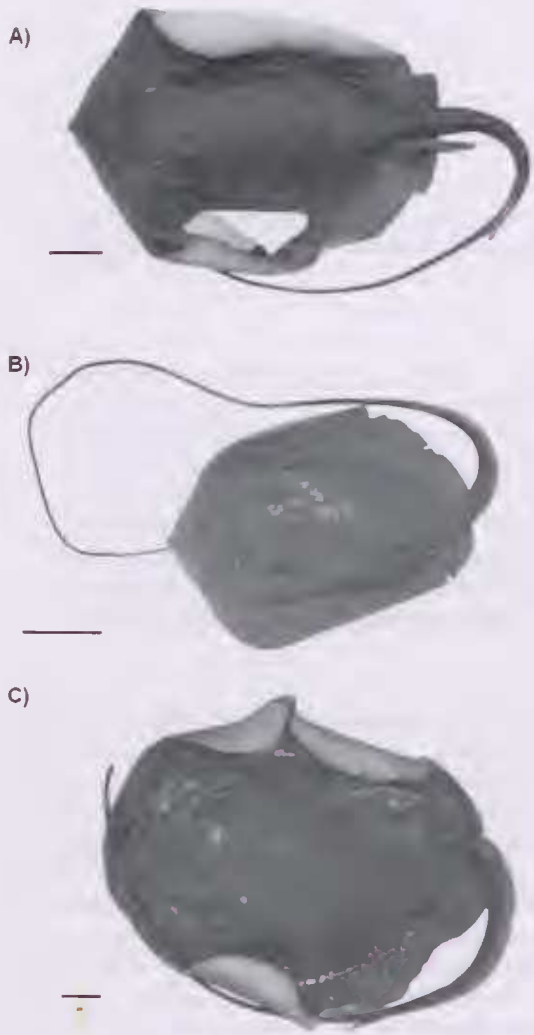

FIG. 1. Nominal *Dasyatis* sp. 1 (White et al., 2006) specimens from Indonesia and northern Australia. A, ANFC specimen H 5286-01 caught in the Kamora River estuary, Papua; B, NTM specimen S.14424-011 caught at Pocock's Beach in the Kakadu National Park; C, NTM S.15930-008 caught in the Keep River estuary, western Northern Territory. Scale bars represent 50 mm.

reviewed and grey literature through searches of published references, CrossSearch (ISI Web of Knowledge) databases and World Wide Web content using internet search engines. Details of museum and other major collection records were obtained through the Online Zoological Collections of Australian Museums (http://www.ozcam.gov.au) which included sightings and records from the Australian Museum (AM), the Australian National Fish Collection (ANFC) and the Museum and Art Gallery of the Northern Territory (NTM). Records from the Queensland Museum (QM) were obtained directly from that institution. Unpublished observations and sighting records were added from interviews with experienced observers. Although data collation focused on positive reports of *D. fluviorum* presence, other major surveys of potential or nominal *D. fluviorum* habitat that did not record the species from certain regions were also noted.

RESULTS

MELANESIA AND NORTHERN AUSTRALIA

Pre-2000 records of *D. fluviorum* from the coasts of eastern Indonesia (Fig. 1A) and Papua New Guinea (PNG) (Kailola 1975, 1987) and more recent observations from the Northern Territory in Australia are likely to have been misidentifications of an undescribed species currently known as the Merauke stingray, *Dasyatis* sp. 1 (White et al. 2006). This species is similarly-coloured to *D. fluviorum* and occupies a similar near-shore and estuarine habitat (White et al. 2006). Photographs of a specimen that was initially identified as *D. fluviorum* (H. Larson pers. comm. Fig. 1B) caught from Pocock's Beach, West Alligator Head, Kakadu National Park, show a long tail and well-developed row of medial thorns. These features are characteristic of *Dasyatis* sp. 1 (White et al. 2006), but are not present in similarly-sized *D. fluviorum* from Moreton Bay (S. Pierce unpub. data). Another, larger specimen from the Keep River estuary in the western Northern

Territory (H. Larson, pers. comm., Fig. 1C), has a similar morphology and these two specimens are provisionally assigned to *Dasyatis* sp. 1

A number of pre-1995 records from the Northern Territory have been shown to be misidentifications of the freshwater whipray *Himantura dalyensis* (Last & Manjaji-Matsumoto 2008) based on descriptions and photographs (Last 2002; Thorburn et al., 2003). Prior to this species being identified from the region, Stead (1963) stated that *D. fluviorum* had been recorded, under synonyms, at Port Darwin in 1878 and 1881 and from the Arafura Sea in 1880. Pollard (1974) caught a single specimen, listed as "*Dasyatis* sp. (*fluviorum*?)", from the East Alligator River and noted that further captures had been made from an adjacent freshwater lagoon. *Dasyatis fluviorum* were not recorded during freshwater elasmobranch surveys in 2002 (Thorburn et al., 2003) or among bycatch of the Northern Prawn Fishery (Stobutzki et al. 2002).

Records of *D. fluviorum* from Darnley Island in the Torres Strait proved to be misidentifications of *Neotrygon kuhlii* (Müller and Henle, 1841). *Dasyatis fluviorum* has not been recorded from fisheries catches in the Gulf of Carpentaria (Blaber et al. 1994; Stobutzki et al. 2002) or from fisheries-independent studies in northern Queensland (Blaber 1990; Blaber et al. 1995). Herbert et al. (1995) conducted a major freshwater fish survey of the Cape York Peninsula region and recorded stingrays from several rivers, listing species as either "*Dasyatis* sp." or "*Dasyatis* sp. (*fluviorum*?)". A photograph in a resulting publication (Herbert and Peeters, 1995) listed as *D. fluviorum* is actually *H. dalyensis*. A more recent survey of freshwater and estuarine elasmobranchs on the peninsula did not record *D. fluviorum*, though *H. dalyensis* was present in the region (Thorburn et al. 2003).

Material. Kamora River estuary, Papua, ANFC H 5286-01 (photograph); Pocock's Beach, West Alligator Head NTM S.14424-011 (photograph); NTM S.15930-008 (photograph); Darnley Island, Torres Strait, QM I 1519, I 1520 (both examined).

CENTRAL AND SOUTHERN QUEENSLAND

The confirmed distribution of *D. fluviorum* extends south from Repulse Bay in central Queensland (20° 37′ S; Fig. 2). There are records of the species from South Beach near Mackay, Warginburra Peninsula north of Yeppoon, Port Curtis near Gladstone (Connolly et al. 2006), Hervey Bay (A. Gutteridge, pers. comm.), Mary River (McPhee & Skilleter 2005), Noosa River (J. Johnson pers. comm.) and the Maroochy and Mooloolah rivers (Schlacher et al. 2005) on the Sunshine Coast. The species is common within Moreton Bay (Johnson, 1999; Pillans et al. 2007) and has been reported to occur in the Brisbane River "above tidal influence" (Ogilby 1908; Stead 1963). *Dasyatis fluviorum* has also been recorded from the Gold Coast Seaway (J. Johnson pers. comm.), Coombabah Creek (Ross 1999), Nerang River (Morton 1989) and Tallebudgera Creek (Morton 1992) on the Gold Coast in southern Queensland.

Material. Repulse Bay, ANFC H 4421-01 (site record); South Beach, Mackay, ANFC H 4595-01 (site record); Warginburra Peninsula, AM I34333008 (site record); Moreton Bay, QM I 26914, I 30175, I 627, ANFC H 5769-01 (site records); Brisbane River, QM I 1530, I 900, I 2101, I 11928, I 235, I 7720 (site records).

NEW SOUTH WALES

The majority of NSW records of *D. fluviorum* were from rivers and harbours. In northern NSW, *D. fluviorum* has been reported from Belongil Creek near Byron Bay (Parker 1999), from between 20 and 28 m depth off the coast east of Iluka, from the Clarence River (Kroon & Ansell 2006) where it has been recorded "at least as far inland as Grafton" (Stead 1963), and the Macleay (Gibbs et al. 1999; Macbeth et al. 2002), Manning (Gibbs et al. 1999), Wallamba (Gibbs et al., 1999), Hunter (Gibbs et al. 1999; Ruello 1976) and Hawkesbury Rivers (Gray 1990). There were records of *D. fluviorum* from Port Jackson between 1881 and 1914, and the species was caught from the Parramatta River and Sydney Harbour between 1975 and 1984 (P. Gibbs pers. comm.). Nine *D. fluviorum* were

caught in Botany Bay fish surveys in 1978 and 1979 (SPCC 1981) and one was caught in April 2000 (Williams et al. 2004). *Dasyatis fluviorum* was listed on a checklist of fishes recorded from the Hacking River (34° 4′ S; Pease & Herbert 2002), and this was the southern-most record of the species.

Material. East of Iluka, ANFC H 4170-01 (site record); Clarence River, ANFC H 5964-01, H 5964-02 (site records); Hawkesbury River, AM I14625, I19951001 (site records); Port Jackson, AM B8395, I13456 (site records).

HABITAT PREFERENCES

Dasyatis fluviorum has been most commonly recorded from shallow coastal waters, particularly over mangrove-fringed sand/mud intertidal flats in sheltered bays and estuarine areas. The maximum depth record was from between 20 and 28 m depth offshore. The species may penetrate rivers to pure freshwater (Stead, 1963), though salinity preferences of 14 - 35 were noted in the Hunter River (Ruello, 1976). Mean monthly surface temperatures at the north of *D. fluviorum*'s distribution (Repulse Bay) range from an estimated 24°C in July to 29°C in January, while the temperature ranges from approximately 17°C in August to 23°C in February near the southern extent of distribution in Botany Bay (Department of Defence, 2007).

DISCUSSION

The results of this study indicate that *Dasyatis fluviorum* is an eastern Australian endemic, restricted to approximately 1700 km of the eastern coast from the Hacking River in NSW (34° 4′ S) in the south to Repulse Bay in Queensland (20° 37′ S) in the north. Considerable sampling effort in tropical north Queensland has failed to record the species (J. Johnson, pers. comm.). The centre of abundance for *D. fluviorum* appears likely to be the sheltered bays and estuaries of southern Queensland based on habitat preferences, distribution data and sighting records. Moreton Bay and Hervey Bay represent two likely population centres (Kyne et al. 2003).

The provisional identification of *Dasyatis* sp. 1 from the Northern Territory is the first record of this species from Australia. *Dasyatis* sp. 1 is not readily distinguishable from *D. fluviorum* (W. White pers. comm.) and is currently known solely from several juvenile specimens from Papua (White et al. 2006). The distinct taxonomic status of *Dasyatis* sp. 1 and the specific identity of Northern Territory *Dasyatis* cf. sp. 1 requires confirmation, as the results of the present study indicate that the extant distribution of *D. fluviorum* is substantially smaller (>50%) than was previously recognised (Last & Stevens 1994).

Recent (post-2000) observations of *D. fluviorum* from the central NSW coast, estuaries and rivers indicate that the southern extent of this species has not contracted northwards in recent decades. This hypothesised range contraction (Last & Stevens 1994; Pogonoski et al. 2002) was used as partial justification for listing *D. fluviorum* as Vulnerable on the IUCN Red List of Threatened Species (Kyne et al. 2003). The revised distribution for the species presented here does not alter the current listing of the species as Vulnerable. In fact, the relatively small range of *D. fluviorum* along the east coast may also add criteria B1ab as an additional risk factor, based on (1) an extent of occurrence of <20000 km^2, (2) possible population fragmentation because of specialised habitat preferences and (3) continued decline in habitat quality in many of the locations where the species is known to occur (IUCN 2001).

Records of *D. fluviorum* are predominantly from tidal rivers, estuaries, sheltered harbours, and only occasionally the adjacent coastline. The extent of this species' interchange between these habitats is unknown. Few data are available on the movement patterns of demersal rays. Short-term acoustic tracking studies on *D. lata* (Garman 1880) (Cartamil

et al, 2003) and *Urobatis halleri* (Cooper 1863) (Vaudo and Lowe, 2006) have shown low rates of movement, while longer-term (months to years) tracking and tagging studies on *D. brevicaudata* (Hutton 1875) (Le Port et al. 2008), *Neotrygon kuhlii* (Pierce et al. 2009) and *U. halleri* (Vaudo & Lowe 2006) have found most individuals to be relatively site-resident. Studies of *D. sabina* (Lesueur 1824) in coastal lagoons found most individuals to be present year-round (Snelson et al. 1988), though two tagged specimens were recaptured 80 and 97 km from the point of tagging along the eastern coast of the United States (Schwartz & Dahlberg 1978). It is unknown how the relatively specialised habitat preferences of *D. fluviorum* affect its dispersal ability, although the single capture of a specimen in 20-28 m depth near the Clarence River mouth may imply that the species is capable of coastal movements. As habitat isolation can increase the overall extinction risk for a species (Reed 2004), determining the extent of interchange between what may be relatively isolated *D. fluviorum* populations is an important topic for future research.

The results of the current survey indicate that *D. fluviorum* faces several contemporary extrinsic threatening processes. Several publications list stingrays as bycatch of near-shore commercial fisheries along the northern and central NSW coasts. These records are ambiguous, recording species as "Dasyatididae/ Urolophidae (mixed spp.)" (Liggins et al. 1996; Liggins and Kennelly, 1996), "*Dasyatis* sp." (Gray 2002), "*Dasyatis* sp. (estuary stingray)" (Gray et al. 2003) or "*D. thetidis* (estuary stingray)" (Gray et al. 2001). However, these areas lie within the revised distribution of *D. fluviorum* and the species is likely to have been a component of these catches. Commercial prawn trawling (Gray et al. 1990; McPhee & Skilleter 2005; Ruello 1976) and estuarine gill net fisheries (Gray 2002), as well as recreational angling (Steffe et al. 2007; West & Gordon 1994) occurs in most known *D. fluviorum* habitats throughout its distribution.

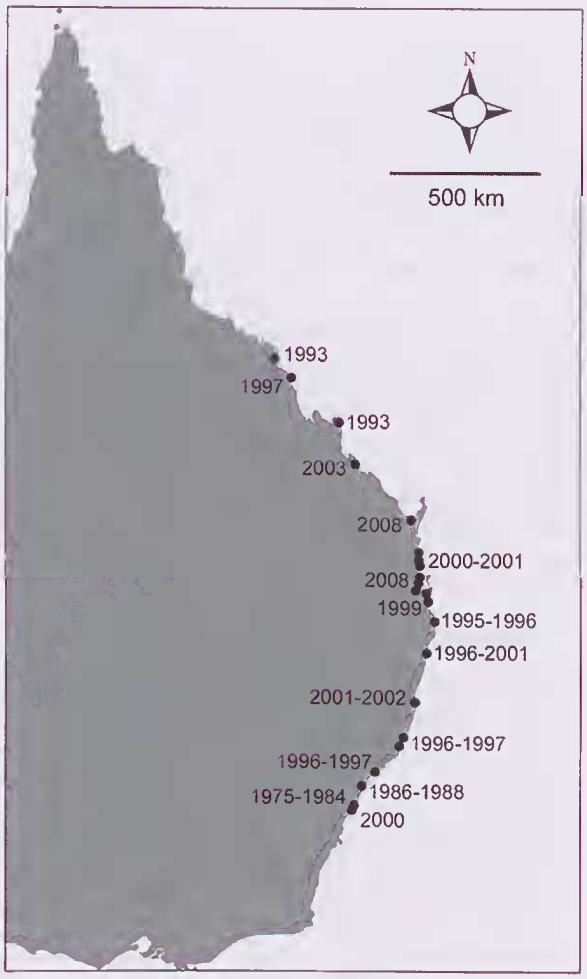

FIG. 2. Confirmed distribution of *Dasyatis fluviorum* on the east coast of Australia with the year last recorded from each site. Hyphenated years indicate the last sampling period during which *D. fluviorum* were recorded.

Habitat modification and degradation are also likely to affect *D. fluviorum*. Many large rivers have been modified through the construction of flood mitigation barriers, which can periodically lead to influxes of water with a low dissolved oxygen content and low pH (Gibbs et al. 1999; Kroon & Ansell 2006) causing fish kills (Macbeth et al. 2002). Occasional fish kills, from a variety of causes, have been noted in many

known *D. fluviorum* habitats (Ruello 1976; Steffe et al. 2007). Many areas are also affected by pollutants (Ruello 1976; Williams et al. 2004), such as excess nitrogen loads (Schlacher et al. 2005) or organochlorines (Birch & Taylor 2000). Potential habitats have also been modified for residential developments such as canal estates (Morton 1992) or commercial industries such as ports (Connolly et al. 2006). Limited data on the use of modified habitats by elasmobranchs in southern Queensland (Morton 1989, 1992; Ross 1999) have not shown *D. fluviorum* to utilise residential canal estate habitats, although the species was present in adjacent unmodified areas. The majority of known *D. fluviorum* habitats, and particularly large rivers and harbour areas, are subject to multiple potential threatening processes (i.e. Birch & Taylor 2000; Johnson 1999; Ruello 1976).

Although anecdotal evidence suggests significant population decline overall (Kyne et al., 2003), *D. fluviorum* has been shown to persist in some highly-modified habitats for long time periods (> 100 years in some cases). It is difficult to ascertain the contemporary abundance of *D. fluviorum* in these habitats. Poor water quality or pollutants has been linked with endocrine dysfunction, health disturbances and decreased reproductive health in elasmobranch populations (Gelsleichter et al. 2005, 2006), which can potentially lead to reduced rates of population growth (Cortés & Parsons 1996). Habitat degradation has also been linked to increased mortality in juvenile sharks and a possible long-term decrease in carrying capacity (Jennings et al. 2008). While these factors have not been examined in *D. fluviorum*, it is possible that reductions in the quality and quantity of habitat have contributed to the species' population decline. Large stingrays are relatively difficult fish to sample because their size, benthic habit and general anatomy makes them difficult to enmesh in nets. Evaluation of their current status and abundance would be assisted by species-specific data collection during trawl surveys in deeper riverine waters and seine-netting in intertidal areas.

The revised distribution of *D. fluviorum* along the eastern coast overlaps with a large proportion of the most urbanised and modified coastal areas in Australia. The reduction, modification and degradation of inshore, and particularly estuarine habitats are likely to directly or indirectly impact upon *D. fluviorum* populations throughout much of this range. The species is also impacted by a variety of threats, such as commercial and recreational fisheries, that are known to directly reduce ray populations. This poorly-known species is worthy of increased attention from conservation managers.

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LITERATURE CITED

Birch, G.F. & Taylor, S.E. 2000. Distribution and possible sources of organochlorine residues in sediments of a large urban estuary, Port Jackson, Sydney. *Australian Journal of Earth Sciences* 47: 749-756.

Blaber, S.J.M., Brewer, D.T. & Harris, A.N. 1994. Distribution, biomass and community structure of demersal fishes of the Gulf of Carpentaria, Australia. *Australian Journal of Marine and Freshwater Research* 45: 375-396.

Blaber, S.J. M., Brewer, D.T. & Salini, J.P. 1995. Fish communities and the nursery role of the shallow

inshore waters of a tropical bay in the Gulf of Carpentaria, Australia. *Estuarine, Coastal and Shelf Science* **40**: 177-193.

Blaber, S.J.M., Brewer, D.T., Salini, J.P. & Kerr, J. 1990. Biomasses, catch rates and abundances of demersal fishes, particularly predators of prawns, in a tropical bay in the Gulf of Carpentaria, Australia. *Marine Biology* **107**: 397-408.

Cartamil, D.P., Vaudo, J.J., Lowe, C.G., Wetherbee, B.M. & Holland, K.N. 2003. Diel movement patterns of the Hawaiian stingray, *Dasyatis lata*: implications for ecological interactions between sympatric elasmobranch species. *Marine Biology* **142**: 841-847.

Compagno, L.J.V. 2002. Freshwater and estuarine elasmobranch surveys in the Indo-Pacific region: threats, distribution and speciation. Pp. 168-180. *In* Fowler, S. L., Reed, T. M. & Dipper, F. A. (eds) *Elasmobranch biodiversity, conservation and management. Proceedings of the international seminar and workshop, Sabah, Malaysia, July 1997.* Vol. 25. Occasional Papers of the IUCN Species Survival Commission. (IUCN: Gland and Cambridge).

Connolly, R.M., Currie, D.R., Danaher, K.F., Dunning, M., Melzer, A., Platten, J. R., Shearer, D., Stratford, P. J., Teasdale, P. R. & Vandergragt, M. 2006. *Intertidal wetlands of Port Curtis: ecological patterns and processes, and their implications*. Technical Report No. 43. (CRC for Coastal Zone, Estuary and Waterway Management: Brisbane).

Cortés, E. & Parsons, G.R. 1996. Comparative demography of two populations of the bonnethead shark (*Sphyrna tiburo*). *Canadian Journal of Fisheries and Aquatic Sciences* **53**: 709-718.

Department of Defence. 2007. Surface temperature search tool. (Database, Directorate of Oceanography and Meteorology, Department of Defence, Commonwealth of Australia). Available from: http://www.metoc.gov.au.

Gelsleichter, J., Manire, C.A., Szabo, N.J., Cortés, E., Carlson, J. & Lombardi-Carlson, L. 2005. Organochlorine concentrations in bonnethead sharks (*Sphyrna tiburo*) from four Florida estuaries. *Archives of Environmental Contamination and Toxicology* **48**: 474-483.

Gelsleichter, J., Walsh, C.J., Szabo, N.J. & Rasmussen, L. E. L. 2006. Organochlorine concentrations, reproductive physiology, and immune function in unique populations of freshwater Atlantic stingrays (*Dasyatis sabina*) from Florida's St. Johns River. *Chemosphere* **63**: 1506-1522.

Gibbs, P., McVea, T. & Louden, B. 1999. *Utilisation of restored wetlands by fish and invertebrates*. NSW Fisheries Final Report Series No. 16. (NSW Fisheries Office of Conservation: Cronulla).

Gray, C.A. 2002. Management implications of discarding in an estuarine multi-species gill net fishery. *Fisheries Research* **56**: 177-192.

Gray, C.A., Kennelly, S.J. & Hodgson, K. E. 2003. Low levels of bycatch from estuarine prawn seining in New South Wales, Australia. *Fisheries Research* **64**: 37-54.

Gray, C.A., Kennelly, S.J., Hodgson, K.E., Ashby, C.J. T. & Beatson, M. L. 2001. Retained and discarded catches from commercial beach-seining in Botany Bay, Australia. *Fisheries Research* **50**: 205-219.

Gray, C.A., McDonall, V.C., & Reid, D.D. 1990. By-catch from prawn trawling in the Hawkesbury River, New South Wales: species composition, distribution and abundance. *Australian Journal of Marine and Freshwater Research* **41**: 13-26.

Halpern, B.S., Selkoe, K.A., Micheli, F. & Kappel, C.V. 2007. Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. *Conservation Biology* **21**: 1301-1315.

Herbert, B. & Peeters, J. 1995. *Freshwater fishes of far north Queensland*. (Queensland Department of Primary Industries: Brisbane).

Herbert, B.W., Peeters, J.A., Graham, P.A. & Hogan, A.E. 1995. *Freshwater fish and aquatic habitat survey of Cape York Peninsula. Cape York Peninsula Land Use Strategy*. (Office of the Co-ordinator General of Queensland: Brisbane, Department of the Environment, Sport and Territories: Canberra, Queensland Department of Primary Industries: Brisbane).

IUCN. 2001. *IUCN Red List Categories and Criteria: Version 3.1*. (IUCN: Gland and Cambridge).

IUCN. 2007. *2007 IUCN Red list of threatened species*. (Database, IUCN). Available from: http://www.iucnredlist.org.

Jennings, D.E., Gruber, S.H., Franks, B.R., Kessel, S. T. & Robertson, A.L. 2008. Effects of large-scale anthropogenic development on juvenile lemon shark (*Negaprion brevirostris*) populations of Bimini, Bahamas. *Environmental Biology of Fishes* **83**: 369-377.

Johnson, J.W. 1999. Annotated checklist of the fishes of Moreton Bay, Queensland, Australia. *Memoirs of the Queensland Museum* **43**: 709-762.

Kailola, P.J. 1975. *A catalogue of the fish reference collection at the Kanudi fisheries research laboratory, Port Moresby*. Research Bulletin No. 16.

(Department of Agriculture, Stock & Fisheries: Port Moresby).

1987. *The fishes of Papua New Guinea. A revised and annotated checklist. Vol. 1. Myxinidae to Synbranchidae.* Research Bulletin No. 41. (Department of Fisheries and Marine Resources: Port Moresby).

Kroon, F.J. & Ansell, D.H. 2006. A comparison of species assemblages between drainage systems with and without floodgates: implications for coastal floodplain management. *Canadian Journal of Fisheries and Aquatic Sciences* **63**: 2400-2417.

Kyne, P.M., Pollard, D.A. & Bennett, M.B. 2003. *Dasyatis fluviorum*. (Database, 2007 IUCN Red list of threatened species). Available from: http://www.iucnredlist.org/search/details.php/41797/summ.

Larson, H.K. 1999. *Report to Parks Australia North, on the estuarine fish inventory of Kakadu National Park, Northern Territory, Australia.* (Museums and Art Galleries of the Northern Territory: Darwin).

Last, P.R. 2002. Freshwater and estuarine elasmobranchs of Australia. Pp. 185-193. In Fowler, S. L., Reed, T. M. & Dipper, F. A. (eds) *Elasmobranch biodiversity, conservation and management. Proceedings of the international seminar and workshop, Sabah, Malaysia, July 1997.* Vol. 25. Occasional Papers of the IUCN Species Survival Commission. (IUCN: Gland and Cambridge).

Last, P.R. & Manjaji-Matsumoto, B.M. 2008. *Himantura dalyensis* sp. nov., a new estuarine whipray (Myliobatoidei: Dasyatidae) from northern Australia. Pp. 283-291. In Last, P. R., White, W. T. & Pogonoski, J. J. (eds) *Descriptions of new Australian chondrichthyans.* CSIRO Marine and Atmospheric Research Paper No. 022. (CSIRO Marine and Atmospheric Research: Hobart).

Last, P.R. & Stevens, J.D. 1994. *Sharks and rays of Australia.* (CSIRO: Australia).

Le Port, A., Sippel, T. & Montgomery, J.C. 2008. Observations of mesoscale movements in the short-tailed stingray, *Dasyatis brevicaudata* from New Zealand using a novel PSAT tag attachment method. *Journal of Experimental Marine Biology and Ecology* **359**: 110-117.

Liggins, G.W. & Kennelly, S.J. 1996. By-catch from prawn trawling in the Clarence River estuary, New South Wales, Australia. *Fisheries Research* **25**: 347-367.

Liggins, G.W., Kennelly, S.J. & Broadhurst, M.K. 1996. Observer-based survey of by-catch from prawn trawling in Botany Bay and Port Jackson, New South Wales. *Marine and Freshwater Research* **47**: 877-888.

Lotze, H.K., Lenihan, H.S., Bourque, B. J., Bradbury, R. H., Cooke, R. G., Kay, M. C., Kidwell, S. M., Kirby, M. X., Peterson, C. H. & Jackson, J. B. C. 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. *Science* **312**: 1806-1809.

Macbeth, W.G., Pollard, D.A., Steffe, A.S., Morris, S. & Miller, M. 2002. Relative abundances of fish and crustaceans and water quality following the fish kill of early March 2001 in the Macleay River, northern New South Wales. Pp. 61-100. In Kennelly, S. & McVea, T. (eds) *Scientific reports on the recovery of the Richmond and Macleay Rivers following fish kills in February and March 2001.* NSW Fisheries Final Report Series No. 39. (NSW Fisheries, Cronulla).

McPhee, D.P. & Skilleter, G.A. 2005. The set pocket (stow) net prawn fishery of the Mary River (Queensland, Australia) and its by-catch. *Proceedings of the Royal Society of Queensland* **112**: 39-46.

Morton, R.M. 1989. Hydrology and fish fauna of canal developments in an intensively modified Australian estuary. *Estuarine, Coastal and Shelf Science* **28**: 43-58.

1992. Fish assemblages in residential canal developments near the mouth of a subtropical Queensland estuary. *Australian Journal of Marine and Freshwater Research* **43**: 1359-1371.

Müller, J. & Henle, F.G.J. 1841. *Systematische beschreibung der plagiostomen.* (Veit & Co.: Berlin).

Ogilby, J.D. 1908. On new genera and species of fishes. *Proceedings of the Royal Society of Queensland* **21**: 1-26.

Parker, P.G. 1999. Fish assemblages at Julian Rocks and the adjacent waters of northern New South Wales, Australia. *Australian Zoologist* **31**: 134-160.

Pease, B.C. & Herbert, S. 2002. Checklist of fishes from the Hacking River catchment, including the Port Hacking estuary, in central New South Wales. *Wetlands (Australia)* **20**: 66-79.

Pierce, S.J., Pardo, S.A. & Bennett, M.B. 2009. Reproduction of the blue-spotted maskray *Neotrygon kuhlii* (Myliobatoidei: Dasyatidae) in southeast Queensland, Australia. *Journal of Fish Biology* **74**: 1291-1308.

Pillans, S., Ortiz, J.-C., Pillans, R.D. & Possingham, H.P. 2007. The impact of marine reserves on nekton diversity and community composition

in subtropical eastern Australia. *Biological Conservation* **136**: 455-469.

Pogonoski, J.J., Pollard, D.A. & Paxton, J.R. 2002. *Conservation overview and action plan for Australian threatened and potentially threatened marine and estuarine fishes*. (Environment Australia: Canberra).

Pollard, D.A. 1974. Report 1. The freshwater fishes of the Alligator Rivers 'Uranium Province' area (Top End, Northern Territory), with particular reference to the Magela Creek Catchment (East Alligator River System). *In* Conway, N. R., Davy, D. R., Giles, M. S., Newton, P. J. F. & Pollard, D. A. (eds). *The Alligator Rivers Fact Finding Study AAEC/E305*. (Environmental and Public Health Division, AAEC: Lucas Heights).

Reed, D.H. 2004. Extinction risk in fragmented habitats. *Animal Conservation* **7**: 181-191.

Ross, J. 1999. *The influence of residential canal estates on estuarine fish assemblages in the Gold Coast region, Australia*. Unpubl. MSc thesis, The University of Queensland, Brisbane.

Ruello, N.V. 1976. Environmental and biological studies of the Hunter River. *Operculum* **June**: 76-84.

Schlacher, T.A., Liddell, B., Gaston, T.F. & Schlacher-Hoenlinger, M. 2005. Fish track wastewater pollution to estuaries. *Oecologia* **144**: 570-584.

Schwartz, F.J. & Dahlberg, M.D. 1978. Biology and ecology of the Atlantic stingray, *Dasyatis sabina* (Pisces: Dasyatidae), in North Carolina and Georgia. Northeast Gulf Science **2**: 1-23.

Snelson, F.F., Williams-Hooper, S.E. & Schmid, T.H. 1988. Reproduction and ecology of the Atlantic stingray, *Dasyatis sabina*, in Florida coastal lagoons. *Copeia* **1988**: 729-739.

SPCC. 1981. *The ecology of fish in Botany Bay. Environmental control study of Botany Bay. BBS 23*. NSW State Pollution Control Commission. Sydney, Australia.

Stead, D.G. 1963. *Sharks and rays of Australian seas*. (Angus and Robertson: Sydney).

Steffe, A.S., Macbeth, W.G. & Murphy, J.J. 2007. Status of the recreational fisheries in two Australian coastal estuaries following large fish-kill events. *Fisheries Research* **85**: 258-269.

Stobutzki, I.C., Miller, M.J., Heales, D.S. & Brewer, D.T. 2002. Sustainability of elasmobranchs caught as bycatch in a tropical prawn (shrimp) trawl fishery. *Fishery Bulletin* **100**: 800-821.

Thorburn, D.C., Peverell, S., Stevens, J.D., Last, P.R. & Rowland, A.J. 2003. *Status of freshwater and estuarine elasmobranchs in northern Australia*. (Report to the Natural Heritage Trust).

Vaudo, J.J. & Lowe, C.G. 2006. Movement patterns of the round stingray *Urobatis halleri* (Cooper) near a thermal outfall. *Journal of Fish Biology* 68: 1756-1766.

West, R. & Gordon, G. 1994. Commercial and recreational harvest of fish from two Australian coastal rivers. *Australian Journal of Marine and Freshwater Research* **45**: 1259-1279.

White, W.T., Last, P.R., Stevens, J.D., Yearsley, G. K., Fahmi & Dharmadi. 2006. *Economically important sharks and rays of Indonesia*. (Australian Centre for International Agricultural Research: Canberra).

Williams, R.J., Bryant, A. & Ledlin, D.E. 2004. *Biodiversity of the Georges River catchment: aquatic biodiversity*. (NSW Department of Infrastructure, Planning and Natural Resources: Sydney).